

The University of Chicago

THE MODIFICATION-REVISION
METHOD IN PSYCHOMOTOR
MEASUREMENT

A PART OF A DISSERTATION SUBMITTED TO
THE FACULTY OF THE DIVISION OF THE
SOCIAL SCIENCES IN CANDIDACY FOR THE
DEGREE OF DOCTOR OF PHILOSOPHY

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THIS article is a summary of an investigation on the modification-revision method in psychomotor measurement. The study was carried out in 1944 at Medical and Psychological Examining Unit No. 10, an installation of the Army Air Forces Aviation Psychology Program (4, 5).

The Modification-Revision Method

The modification-revision method in psychomotor measurement was developed basically as a technique for securing additional measures of performance from existing apparatus tests. For example, the subject in operating a psychomotor test involving manipulation of a stick similar to that of a plane exerted varying degrees of grip pressure. A *modification* was designed to extract a measure of this hand pressure during the performance on the basic test. Similarly, the *revision* was developed to secure an additional measure of performance from existing apparatus tests by increasing the complexity of the problem of the basic test. The subject might be required to solve a second problem simultaneously with that of the basic test, thus dividing his attention between two stimuli; or he might be required to solve the problem of the basic test when its stimulus situation had been altered. The basic tests employed in the study were the *Complex Coordination Test* and the *Rudder Control Test* used in the Aviation Psychology Program for the classification of aircrew candidates (4).

The *modification* measure may thus be described as a "test within a test." It was postulated that while the subject was solving the problem of the basic test, he was employing skills

¹ This study was conducted as part of the AAF Aviation Psychology Program.

that were not being measured by the basic test score. The hypothesis underlying the development of modifications was based upon previous civilian (3) and military (8, 9) research on the measurement of visceral and muscular behaviors accompanying the solution of a problem situation. Modification measures were developed to sample such secondary behaviors as hand and leg tension and motility in the operation of the controls of the basic test, precision and steadiness in the control operation, and reaction to a pattern configuration by the movement of the controls.

The *revision* measure may similarly be described as a "test upon a test." It was postulated that the addition of a further problem to be solved simultaneously with that of the basic test would increase the complexity of the function that the basic test was measuring. The hypothesis underlying the development of revisions was based upon previous civilian (1) and military (4, 7) research on the measurement of reaction to a stress situation. In this study there were developed such second problems, in addition to the basic task, as throttle manipulation, counteraction of external control pressures, and target sighting; and such changes in the stimulus situation of the basic test as auditory rather than visual presentation, a moving rather than a stationary target, simultaneous rather than discrete control movement, and memory rather than perception of light positions.

Development of modifications and revisions was considered important for three reasons: (1) The modification-revision method could effect economy of testing time and apparatus. (2) Proper selection of the secondary and additional problems might add significantly to the validity of methods of aircrew selection. (3) Previous studies of concomitant behavior and stress measurement had been shown efficient in measuring the emotional components of problem solution, and such measurement was particularly applicable to aircrew selection.

Construction of the Modifications and Revisions

Two standards were employed in the construction of the modifications and revisions. These were concerned with the

behavioral function to be measured and the routine mechanics of presenting the test problem to the subject. It was recognized that a later statistical analysis would verify adherence to the proper standards of construction.

The functions measured and the types of problem employed in the construction of the modifications and revisions were selected from two sources. Where possible, the performance to be extracted from or added to the basic test was a function already shown to be valid *per se* for the prediction of aircrew success. In selecting problems where no previous research was available, the face validity of the function as indicated in the job analyses of aircrew performance was required. In the choice of function, an attempt was made to select those problems which would be statistically independent of current predictive instruments.

In building the apparatus and presenting the test problem to the subject, care was taken to eliminate any variables which might affect the normality, objectivity, or consistency of the measurement.

The Hand-Pressure Modification of the *Complex Coordination Test* will serve as an illustration of the construction of a modification. The *Complex Coordination Test* was described in a recent article on AAF psychomotor tests (8). This basic instrument had been designed to measure serial hand-foot coordination in the operation of the stick and rudder bar of a plane, and required the subject to match three movable green lights (controlled by a stick and rudder bar) with patterns of three stationary red lights. The Hand-Pressure Modification had been preceded in civilian literature by the Luria studies (3), and in aviation psychology literature by research in the CAA Program (9) and at Psychological Research Unit No. 1 (7). This Hand-Pressure Modification was proposed in January, 1944, and suggested three major improvements of former methods: (1) The score was to be obtained by clock recording of the time length that grip pressure was maintained above a given level. (2) The hand to be measured was the one operating the stick of the apparatus, thus affording a measure of muscular tension in a voluntary act where the movement

measured was an integral part of the response being studied. (3) The subject was unaware that a secondary score was being obtained in that the stick of the modified *Complex Coordination Test* was not visibly different from the stick of an unmodified apparatus.

The aircrew correlate to be predicted by the Hand-Pressure Modification was defined as the tension on the stick in the operation of the plane. The modification was aimed primarily at the job of the pilot, but analyses of the duties of the navigator and bombardier as well had emphasized the need for absence of tension, confusion and nervousness, and fear and apprehension in aircrew performance. In view of the similarity of the basic *Complex Coordination* apparatus to the instruments used in the flying situation, the measurement of stick tension in this apparatus possessed high face validity for the prediction of similar stick tension in the piloting situation.

The Hand-Pressure Modification was constructed by modifying the stick of the *Complex Coordination Test*. Electrical contact points were inserted inside the grip section of the stick. When hand pressure on the stick reached a given amount, these contact points closed and activated a standard electric timer. As long as the hand pressure continued, the clock score was recorded. When pressure on the stick was relaxed, electrical contact was broken and the clock stopped. A high clock score thus indicated an excessive amount of hand pressure exerted on the stick during the operation of the basic test; a low score, a minimal amount of tension. The hand-pressure score was collected during the eight-minute administration of the *Complex Coordination Test*.

The Throttle-Control Revision of the *Complex Coordination Test* will serve as an illustration of the construction of a revision. The Throttle-Control Revision was designed to measure the division of attention by the addition of a pursuit task requiring simultaneous solution with the *Complex Coordination Test* problem. The aircrew function to be predicted by the revision was defined as divided attention in the operation of the controls of a plane. Actually, the division of attention trait was a requirement for all aircrew positions, but appeared from

the job analyses and from other research studies to be a specific factor. The Throttle-Control Revision of the *Complex Coordination Test* placed emphasis upon an aspect of this ability required for pilot performance. Face validity was achieved in this revision by duplicating the situation of divided attention in piloting a plane, and by the use of throttle manipulation as the simultaneous problem to be solved. Previous research on pursuit problems had shown the validity of this type of problem in itself (8). The combination of the pursuit function with the proven coordination task held the possibility of both cumulative validity and of sampling the division-of-attention trait.

The revision apparatus was constructed on the principle of the Miles pursuitmeter. It employed an ammeter, with the face of an airspeed indicator superimposed on the dial. The needle of the ammeter was mechanico-electrically moved across the dial face in a random forward-backward pattern by an automatic disturber unit. A tolerance area was marked on the dial face, and excursion of the needle outside these limits resulted in the disappearance of the stimulus lights of the *Complex Coordination Test*. Forward-backward movements of a throttle lever acted as a rheostat and resulted in the increase or decrease of the airspeed and thus the control of the ammeter needle. The task of the subject was to divide his attention between the matching of the red-green lights of the *Complex Coordination Test* by the operation of the stick and rudder controls, and the maintenance of the airspeed indicator within the specified tolerance limits by the forward-backward movements of the throttle lever. Failure to maintain a proper adjustment of the airspeed indicator resulted in the disappearance of the stimulus lights. Observation showed both problems to be sufficiently simple to allow their simultaneous solution, and attention to both tasks to be the only method of attaining efficient performance. The score employed was the number of patterns of the *Complex Coordination Test* matched while simultaneously adjusting the airspeed indicator. Performance was judged in four continuous trials of two minutes each.

Analysis of the Modifications and Revisions

The modifications and revisions were analyzed with reference to a series of statistical requirements to verify their adherence to the criteria of test construction. In view of the fact that this study was conducted at a Medical and Psychological Examining Unit (4), emphasis was placed upon the so-called pre-validation standards of analysis. The three pre-validation criteria employed by the writer required adherence of the modification and revision measures to standards of distribution, reliability, and independence. If further study were warranted, AAF Training Command Headquarters (6) assigned the measure a validation priority at the Department of Psychology, School of Aviation Medicine (8).

In terms of distribution, normality in the arrangement of test scores was required. For consistency of measurement, an odd-even reliability of at least .75, uncorrected for length, was postulated. The criterion of independence was met if the modification or revision correlated below .60 with the basic test, and below .40 with the test and stanine scores of the Aviation Psychology Classification Battery (6).² The fourth analysis standard of validity was that employed throughout the Aviation Psychology Program (6).

Analysis of the Hand-Pressure Modification scores of three hundred aviation cadets showed this modification to afford a normal distribution of scores, high reliability of measurement (.89), and little relationship with the current AAF *Complex Coordination Test* (.10), stanine scores (-.03 to .07), or Classification Test Battery (-.08 to .08). On the basis of the pre-validation analysis, the Hand-Pressure Modification could make a contribution to the multiple correlation of the AAF Battery with pilot proficiency if it attained a minimum validity of .13. In a validation study of this modification carried out at

² The Aviation Psychology Classification Battery consisted of approximately 14 printed and 6 psychomotor tests, which measured verbal, mechanical, perceptual speed, numerical, motor coordination, inductive reasoning, visualization, space relations, science education, and aviation interest abilities. The AAF tests were individually weighted and then combined to afford a composite score for prediction of pilot, navigator, and bombardier training success. This composite score was expressed on a nine-point scale in standard deviation units and hence was termed a stanine score.

the School of Aviation Medicine, biserial correlations of .19 ($N=209$) and $-.02$ ($N=950$) with graduation-elimination from elementary pilot training were reported.

The analysis of Throttle-Control Revision data for three hundred aviation cadets afforded a normally distributed curve of revision scores with a mean score of 18 as contrasted with the average Complex Coordination score of 74. The odd-even reliability constant was .74. Correlation between the *Complex Coordination Test* and its Throttle-Control Revision was found to be .43. Relationship of the revision with the AAF pilot stanine was .24 as contrasted with the Complex Coordination pilot stanine correlation of .69. On the basis of its correlation with the pilot stanine, the Throttle-Control Revision was capable of raising the pilot stanine validity from .50 to .55, if the revision attained a validity of .34. A revision validity as low as .22 would be productive of some increase in predictive efficiency. AAF Battery inter-correlations of the Throttle-Control Revision ranged from $-.02$ to .22, a median decrease of eighteen hundredths from battery correlations reported for the basic *Complex Coordination Test*. No validation data on the revision are available.

A total of twelve modifications and nine revisions of the AAF *Complex Coordination Test* and *Rudder Control Test* were developed. The results of construction and analysis are summarized below, and Table 1 presents the pertinent statistics determined in the pre-validation analysis.

Pressure exerted in the operation of the stick and rudder controls exhibited a high consistency of measurement and little relation between such assessment of muscular tension and AAF Battery measures. Pressure scores showed some communality with each other, moderate relationship with other measures of muscular activity, and a slight tendency toward prediction of performance inhibition. Hand and leg pressure during the operation of both the *Complex Coordination Test* and the *Rudder Control Test* was apparently a psychological function which was unsampled by AAF measures and which possessed a good amount of face validity for aircrew prediction. The Hand-Pressure Modification of the *Complex Coordination Test*

TABLE 1
Pre-Validation Statistics of the Modifications and Revisions (N = 300)

	Odd-even reliability	Correlation basic test	Correlation AAF battery	Correlation AAF pilot stanne	Minimum validity pilot required
AAF COMPLEX COORDINATION TEST					
<i>Modifications</i>	.87		.06 to .47	.69	
Hand-Pressure Modification	.89	.10	-.08 to .08	.07	.13
Foot-Pressure Modification	.90	.04	-.06 to .06	.00	.12
Seat-Pressure Modification	.93	.03	-.14 to .08	-.06	.12
Accuracy Modification	.78	.13	-.06 to .15	.09	.14
Gestalt Modification	.67	.89		.63	.39
Time-Dimension Modification	.82	.38	-.05 to .24	.34	.26
<i>Revisions</i>					
Throttle-Control Revision	.74	.43	-.19 to .22	.24	.22
Control-Pressure Revision	.66	.82		.58	.37
Red-Light-Memory Revision	.69	.58	-.04 to .48	.48	.32
Auditory-Instructions Revision	.60	.51	.03 to .51	.39	.29
Simultaneous-Control Revision	.79	.17	-.24 to .20	.14	.17
AAF RUDDER CONTROL TEST					
<i>Modifications</i>	.89		-.06 to .32	.52	
Hand-Pressure Modification	.92	.16	-.05 to .11	.13	.16
Foot-Pressure Modification	.94	.07	-.09 to .07	.07	.13
Seat-Pressure Modification	.92	.05	-.13 to .12	.06	.12
Pedal-Movement Modification	.90	.33	-.14 to .21	.26	.23
Stick-Movement Modification	.66	.48		.35	.26
Target-Steadiness Modification	.84	.67		.37	.27
<i>Revisions</i>					
Moving-Target Revision	.78	.30	-.04 to .16	.14	.17
Machine-Displacement Revision	.91	.39	-.15 to .14	.12	.16
Target-Sighting Revision	.61	.27	.01 to .19	.26	.23
Bank-Control Revision	.78	.42	-.08 to .32	.37	.27

best satisfied the pre-validation criteria and was recommended, as a test case, for validation analysis. Validation data as reported above were not conclusive.

The movement of the limbs during the operation of the Rudder Control pedal and stick showed an adequate reliability and some relationship between the motility of the rudder and stick and the AAF Battery measures. Modification scores were moderately related for hand and foot movements, and measured functions in common with the *Rudder Control Test* and the secondary performances of hand pressure and precision of target coordination. Pedal motility was considered sufficiently non-duplicative of current predictive measures to afford an independent contribution and thus to warrant a validation study. A validity coefficient of .05 with graduation-elimination from elementary pilot training was reported by the School of Aviation Medicine.

Precision in pursuit coordination as measured by the ability to maintain alignment of the follower and target was found to be an aspect of basic test performance already inherent in the basic test score. A study of errors in coordination was carried out in the pursuit problems of the AAF *Rudder Control Test*, the *Rotary Pursuit Test*, and the *Two-Hand Coordination Test*. It may be stated that the measurement of the number of times that the target-follower contact is broken is a secondary aspect of behavior already accounted for in the basic test performance. One exception to this conclusion was found in the study of excess contacts with the correct lights of the *Complex Coordination Test*. Accuracy of matching bore no relation to the number of patterns completed nor to recognized measures of arm-hand steadiness; and thus made the nature of the function being measured difficult to define.

The length of time spent in the manipulation of the *Complex Coordination Test* problems showed two characteristics. Measurement of the time spent on the total pattern appeared to sample the speed of reaction rather than the simultaneity of control movement, and was found highly related to the basic test score. Measurement of the time spent in aligning the upper row of lights showed some probability of battery contribution.

The Throttle-Control Revision, as previously discussed, required the subject to solve the Complex Coordination task simultaneously with a pursuit problem. The new problem-situation preserved the Complex Coordination function, but added sufficient new abilities to require a minimum validity of .21 for the revision to contribute to the predictive efficiency of the current battery.

The Control-Pressure Revision required the subject to discriminate between and to counteract external pressures in operation of the stick control of the *Complex Coordination Test*. Construction inadequacies resulted in the failure of the revision to meet the pre-validation standards. In view of the success of the similar Machine-Displacement Revision of the *Rudder Control Test*, further preliminary study of this revision was recommended.

The Red-Light-Memory Revision required the subject to recall the light positions in order to match the patterns of the *Complex Coordination Test*. The correlation of this revision with the basic test, stanines, and AAF battery measures indicated its enlargement of the functions measured by the *Complex Coordination Test*, but in the direction of already existent predictors.

The Auditory-Instructions Revision required the subject to match the Complex Coordination stimulus lights with the number positions presented orally. This auditory-perceptual ability was found moderately related to basic test and stanine measures, but still capable of separate contribution to the effectiveness of the battery. When confusion sounds were added as a background to the auditory instructions, the revision was found unrelated to AAF aptitude measures, and capable of significant contribution.

The Simultaneous-Control-Movement Revision required the subject to operate the Complex Coordination controls simultaneously rather than serially. It showed low correlation with current predictive measures and was apparently worthy of further investigation.

The Moving-Target Revision of the *Rudder Control Test* required the subject to coordinate rudder-bar movements to

follow a target across a horizontal path. Study of this increase in difficulty showed that it retained a good measure of Rudder Control performance, but that it also added sufficient new skills to lower significantly the correlation between basic test and stanine for efficient contribution.

The Machine-Displacement Revision required the subject to discriminate between and to counteract pressures externally imposed to displace the Rudder Control apparatus. The Rudder Control function again remained in sufficient amount to warrant some retention of its validity, and at the same time stanine correlations decreased so as to allow battery contribution if the revision showed a minimum validity of .15.

The Target-Sighting Revision required the subject to indicate apparatus-target alignment by the depression of a gun-firing button mounted on top of the Rudder Control stick control. Accuracy in such visual perception was moderately related to a number of AAF Battery measures, but the revision still appeared capable of making a contribution to the multiple correlation of the battery.

The Bank-Control Revision measured a function similar to that sampled in the Throttle-Control Revision of the *Complex Coordination Test*, and exhibited comparable analytical data.

Summary

In terms of the study of the modification-revision method, it may be concluded that:

Basic instruments of proven predictability may be modified for extraction of secondary performance scores and revised by adding second problems for the enlargement of basic test function.

Such concomitant behaviors and enlarged functions are not universally being measured by the basic test score.

Depending upon the nature of the specific modification or revision, such measures may make a contribution to the predictive efficiency of a battery of tests.

The value of a modification or revision, which satisfies the pre-validation and validation criteria, would be such a contribution with little additional expense in testing time and apparatus.

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